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# MEXACARBATE and BACILLUS THURINGIENSIS for control of PINE BUTTERFLY INFESTATIONS

## Bitterroot National Forest, Montana...1973

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# MEXACARBATE AND *BACILLUS THURINGIENSIS* FOR CONTROL OF PINE BUTTERFLY INFESTATIONS BITTERROOT NATIONAL FOREST, MONTANA 1973

Cover photo: Bell 47G-3 applying mexacarbate to ponderosa pine stand infested by pine butterfly in the Bitterroot Valley, Montana--1973. Pink color of spray cloud is due to addition of Dupont oil red dye for spray deposit assessment. Yellow cloud in forest canopy at lower left is a smoke grenade used to monitor local air currents during spray application.

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# MEXACARBATE AND *BACILLUS THURINGIENSIS* FOR CONTROL OF PINE BUTTERFLY INFESTATIONS - BITTERROOT NATIONAL FOREST MONTANA - 1973 [1/]

by

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## ABSTRACT

Aerial application of mexacarbate and *Bacillus thuringiensis* Berliner was tested against pine butterfly, *Neophasia menapia* (F. and F.). These were applied to 40-acre plots on the Bitterroot National Forest and adjacent State and private lands during June 1973. Two concentrations of each material were tested; these were 0.15 and 0.30 pound per acre of mexacarbate, and 0.5 and 1.0 pound of *B. thuringiensis* per acre. Both concentrations of mexacarbate caused pine butterfly population reductions of near 97 percent and *B. thuringiensis* provided 73 percent reduction at the 0.5 pound rate and 92 percent at the 1.0 pound rate. Natural decline of late instar larval population precluded an evaluation of differences in degree of defoliation between treated and untreated areas.

## INTRODUCTION

Pine butterfly, *Neophasia menapia* (F. and F.), periodically reaches epidemic levels in ponderosa pine, *Pinus ponderosae* (Laws.), forests of the western United States and Canada. At least five major outbreaks, including the current one, have been documented since the late 1800's (Cole 1956). All outbreaks prior to 1953 were permitted to run their course with no control attempted resulting in tree mortality of up to 90 percent in some infested stands (Hopkins 1907). Evenden (1940) reported radial growth reductions of over 70 percent due to defoliation by

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1/ This paper reports work involving chemical and biological insecticides. It does not include recommendations for their operational use nor does it imply that uses discussed here have been registered. All uses of pesticides must be registered by appropriate State or Federal agencies or both before they can be recommended.

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this insect. He observed reduced growth rates for up to 13 years following the outbreak. In 1951 a 169,000-acre infestation on the Boise National Forest was sprayed with DDT which was credited with reducing the outbreak to endemic levels. Tree mortality 5 years after the epidemic was only 1.3 percent (Cole 1966).

Large numbers of conspicuous white pine butterflies (Fig. 1), were observed in 1968 and 1969 on parts of the Bitterroot National Forest.

Figure 1.--Pine butterfly adult

By 1970 larval populations began causing light defoliation at scattered locations (Ciesla et al. 1971a). Aerially visible defoliation increased to about 10,000 acres in 1971 and to 40,000 acres in 1972 (Bousfield and Dewey 1972). Trees in some areas, particularly the drier south-facing slopes, were entirely defoliated (Fig. 2). Egg mass surveys in early autumn 1972 indicated that additional feeding injury would occur in 1973. Recognizing the insect's reputation as a "tree killer" and the facts that DDT had been the only chemical ever applied to control pine butterfly infestations and no materials are currently registered for use against this insect, a field experiment was initiated in 1973 on the Bitterroot

Figure 2.--Heavy defoliation of ponderosa pine by pine butterfly.

National Forest in an attempt to develop alternative control methods. The cooperative test utilizing aerial spray technology involved a multidiscipline team of scientists representing the Bitterroot National Forest, Missoula Equipment Development Center, State and Private Forestry, Northern Region, USFS; Insecticide Evaluation Project, Pacific Southwest Forest and Range Experiment Station; and Dugway Proving Grounds, U.S. Army, Dugway, Utah.

## METHODS

Materials tested.--Lyon and Brown (1971) reported that 12 chemicals were more toxic to pine butterfly than DDT in the laboratory. The testing team selected the insecticide mexacarbate (Zectran)[6/] from this list of candidate compounds for testing because of the extensive volume of data on environmental safety of this material from previous tests on other forest defoliators plus its toxicity to the intended target--the pine butterfly--as established by laboratory tests. Two dosage rates were used, 0.15 pound and 0.30 pound active mexacarbate per gallon of No. 2 fuel oil/acre.

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6/ 4-dimethylamino -3, 5,- xylylmethyl carbamate registered trademark - Dow Chemical Co., Midland, Michigan. (Mention of commercial products in this report is for convenience only and does not imply endorsement by U.S. Department of Agriculture.

The microbial insecticide, *Bacillus thuringiensis*, Berliner also was tested. Studies in the Bitterroot Valley in 1972 by Dr. Clarence H. Thompson, Pacific Northwest Forest and Range Experiment Station, Corvallis, Oregon, showed this material to be toxic to instars III and IV under field conditions.[7/] In addition, laboratory bioassays of several dosage rates of *Bacillus thuringiensis* ranging from 0.10 pound to 1.0 pound/100 gallons of water indicated that all dosages produced 100 percent mortality of instar II, III, and IV larvae within 5 days.[8/] Two dosages of *B. thuringiensis* were field tested, 0.5 pound and 1.0 pound Dipel[9/] wettable powder in 2 gallons of water per acre. A commercial surfactant, Biofilm, was added at the rate of 16 ounces per 100 gallons spray.[10/]

Control strategy.--Strategy for mexacarbate, a contact insecticide, was to apply spray as soon as possible after 100 percent of the viable eggs hatched within a given set of treatment replicates, thus treating early instar larvae and maximizing foliage protection. This was possible in the case of pine butterfly because at a given elevation, eggs tend to hatch within a 5- to 6-day period.

*Bacillus thuringiensis*, a stomach toxicant, must be ingested in order to be effective. Therefore, application was delayed until most of the larvae had reached instar III, a stage at which they are actively feeding, thus increasing the probability of ingesting foliage containing spray deposit.

Test design and plot establishment .--Experimental blocks were located in pure or nearly pure stands of low elevation ponderosa pine 60 to 80 years of age in the Bitterroot Valley between Florence and Darby, Montana. All but one of the blocks were located on the west side of the Bitterroot Valley (Fig. 3) and all but two were on National Forest land. Each treatment was applied to a series of three 40-acre (20- by 20-chain) blocks. In addition, three blocks were left untreated to serve as check or control blocks. The following criteria had to be met in order for an area to be included in the test:

1. A substantial overwintering pine butterfly population (at least five viable eggs per 5-inch branch tip).

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7/ Data on file, Pacific Northwest Forest Experiment Station, Forestry Sciences Laboratory, Corvallis, Oregon.

8/ Data on file, State and Private Forestry, USDA Forest Service, Missoula, Montana. The authors acknowledge the assistance of Dr. S. Seimer, Abbott Laboratories, Fresno, California, for conducting laboratory bioassays of Dipel against pine butterfly during April 1973.

9/ Registered trademark, Abbott Laboratories, N. Chicago, Illinois.

10/ Dr. Phillip A. Grau, Abbott Laboratories, Fresno, California, assisted with field formulation of Dipel.

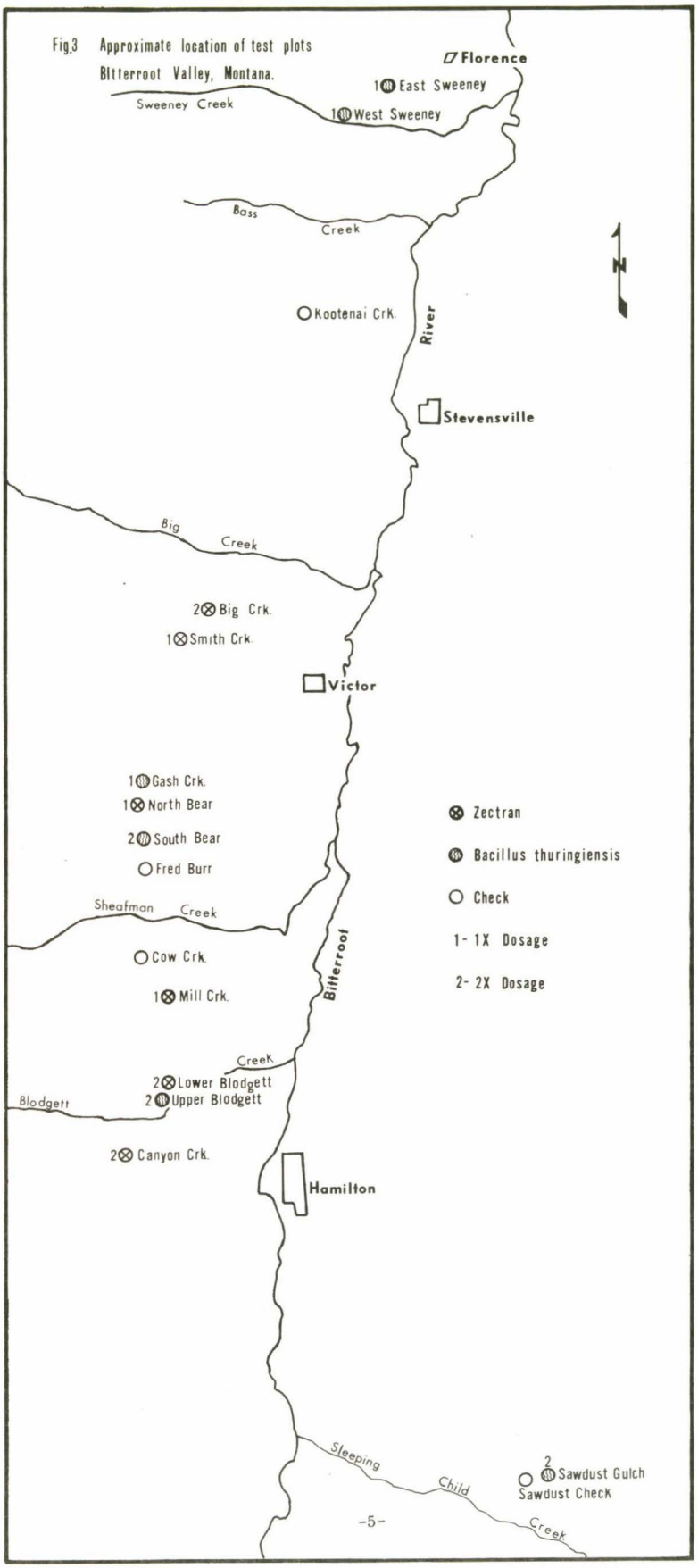


Fig.3 Approximate location of test plots Bitterroot Valley, Montana.

2. Most trees in the stand with not more than one-third of the foliage removed by previous year's feeding.

3. Terrain that was conducive to helicopter spraying.

4. Good accessibility (not more than 1 mile from road).

5. Sufficient open grown ponderosa pine, 30 to 60 feet tall, thus permitting repeated pole pruner sampling from midcrown.

Study plots were located so as to reduce the risk of contamination from one plot to another. A meteorologist assisted in plot orientation relative to expected air movement patterns.

Boundaries of each treatment block were marked with flagging tape clearly visible from the ground. Corners were marked with fluorescent streamers located in tops of the dominant tree nearest to the plot corners. Streamers were positioned in tops of trees by shooting a line over the tree with a

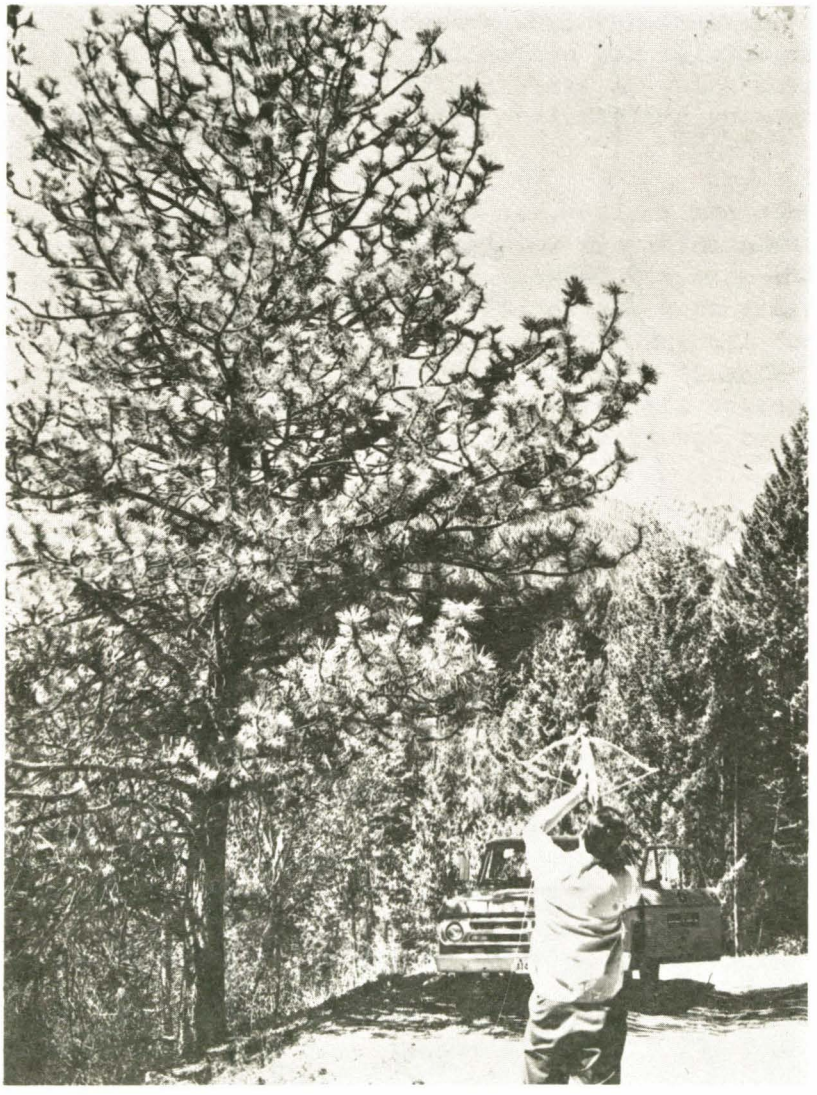

Figure 4.--Marking spray block corner tree with crossbow.

crossbow and pulling the streamer into the tree's crown (Fig. 4 and 5). These corner markers were conspicuous from the air and assisted spray pilots with locating plots, and provided reference points to help in gauging swath width.

Figure 5.--Spray block corner tree with flagging.

Sample size.--Sample size for measuring prespray and postspray larval population levels was based on an egg mass survey developed in 1971 and 1972 for predicting defoliation (Ciesla et al. 1971a; Bousfield and Meyer 1972; Bousfield and Dewey 1972). Cluster samples consisting of five 10-tree clusters per block were located and marked for repeated sampling. Six branches were collected from each sample tree for a total of 300 branches per area each sample period.

There were insufficient sample trees of a single size class suitable for sampling; therefore, trees of varying heights were sampled. All samples were collected from 20 to 30 feet above the ground. Basic sample unit was six branches, each approximately 12 inches long.

Prespray and postspray sampling.--Informal development samples were collected to establish when to begin spraying. Partial egg hatch was observed as early as May 21. Uniform development sampling began May 25. Development samples were collected in the same manner and locations as the population samples, but not from the same trees. This gave field crews an opportunity to become proficient with pole pruners, locate sample trees, and familiarize themselves with the procedures of bagging and transporting samples.

Prespray samples were collected no more than 48 hours prior to spraying. For the mexacarbate test a single postspray sample was collected 4 days after spray application. Postspray samples were taken from the plots treated with *Bacillus thuringiensis* at 4-, 8-, and 12-day intervals.

Prespray and postspray sampling consisted of removing six branches approximately 12 inches long from each sample tree with extendable pole pruners equipped with a canvas catch bag to assure collection of dislodged larvae. Sample branches and larvae were placed individually in plastic bags and taken to a temporary field laboratory in Stevensville, Montana, for processing. Caution was taken to keep bags shaded to prevent larva mortality from overheating.

All branch samples were systematically examined in the laboratory for presence of living and dead pine butterfly larvae. Population densities were expressed as numbers of larvae per linear inch of foliated branch.

Aircraft and spray system.--Two Bell 47G-3 helicopters were used to apply the insecticide and a third was equipped with a closed-circuit television camera to monitor spraying and track the spray helicopters (Jasumback 1974). A Cessna 185 was used as a spotter plane.

Spray helicopters were equipped with a conventional spray system capable of carrying 70 gallons of insecticide; however, these were loaded with a maximum of 50 gallons for safety reasons. Spray booms contained 30 and 59 spray tips (80015 Spray Systems, Inc.) for the mexacarbate test and Bt test respectively. A pressure of 40 pounds/square inch and airspeed of 50 m.p.h. were maintained to provide a droplet size of approximately 250 microns VMD (volume median diameter). Nozzles were attached to the boom perpendicular to the line of flight. Swath width was 50 feet, airspeed was 45 m.p.h. and a flying height of 50 feet above the tree crowns was maintained by the spray aircraft.

Meteorology.--A meteorological station was operated in each spray block prior to and maintained during spray operation. Meteorological parameters measured included temperature, relative humidity, wind velocity and direction, cloud conditions, and presence or absence of an inversion layer. A wiresond weather balloon inflated with helium was used to take vertical temperature profiles at 10-foot intervals from ground level to 150 feet (Fig. 6). Location of inversion layers was detected by these readings.

Figure 6.--Wiresond weather balloon used to measure vertical temperature profile.

As the spray helicopter approached the spray block a smoke grenade was discharged (Fig. 7) to give the pilot exact wind direction and an indication of velocity at moment of spray release. As a result he could compensate for air current by beginning the first spray run either upwind or downwind of the spray block boundary.

Figure 7.--Discharging smoke grenade to monitor local air currents in spray block.

Spray deposit assessment.--An intensive spray assessment effort was conducted by personnel of U.S. Army Dugway Proving Ground and Missoula Equipment Development Center. A detailed report on results of this study will be published at a later date. For purpose of this report, however, only spray deposit assessment relating directly to deposit-mortality analyses will be described.

Two dyes were added to the spray mixtures--Dupont oil red (CI258) to the mexacarbate at a concentration of 0.4 grams/100 cc. and Rhodamine B "extra S" water soluble dye to the *Bacillus thuringiensis* at the rate of 0.125 gram/100 cc. liquid. White printflex cards on stainless steel trays were placed immediately prior to spraying at each sample tree in four cardinal directions, and in a cross configuration through each block and in open areas. Cards were collected immediately after each day's spraying was completed. (Figure 8)

Figure 8.--Spray deposit under forest canopy on white printflex card.

Spray cards were analyzed by Los Alamos Scientific Laboratory, Los Alamos, New Mexico, by an automated spot counter and sizer. Spray droplet densities were expressed in $mg/m^2$ for each card and droplet volume median diameter was determined.

Assessment of foliage protection.--Data on degree of foliage protection and insect mortality were desired. Therefore, plans were made to provide color infrared aerial photo coverage of each spray block in late July at time of peak pine butterfly defoliation. Plans called for stereo coverage of each block at a photo scale of 1:15,840. From these, varying intensities of feeding injury could be mapped relative to boundaries of spray blocks (Ciesla et al. 1971b).

Impact on nontarget insects.--A drop cloth 1 yard square was positioned under one of the sample trees in each cluster in the mexacarbate plots to monitor the effect on nontarget insects. Contents of each drop cloth were collected 4 hours after spraying. Specimens were taken to the laboratory for identification by an entomologist. Drop cloths were not used in the Dipel plots because documentation exists on the effect of *Bacillus thuringienses* on nontarget insects.

Inform and involve program.--I&I program relating to this project was a coordinated effort involving the Bitterroot National Forest and the Northern Region's Information & Education and State & Private Forestry. It consisted of:

1. A number of timely news releases to newspapers and television and radio stations in Missoula and Hamilton, Montana.

2. Preparation and dissemination of an environmental analysis report wherein the anticipated impacts of the proposed action were examined.

3. Preparation of three pictorial displays illustrating the problem and briefly explaining the proposal (Fig. 9 & 10). These were placed in public places such as banks, courthouses, and Federal buildings in Missoula, Hamilton, and Victor, Montana.

4. Presenting the proposed action to such key groups as Ravalli County Fish and Wildlife Association; Bitterroot RC&D; Montana Fish and Game Department; School of Forestry, University of Montana; Ravalli County Commissioners, plus other key individuals.

5. Conducting a public meeting in Hamilton to present the proposal and receive input into the test plan.

6. Television and newspaper coverage of the actual spraying.

PINE BUTTERFLY LIFE CYCLE
EGGS deposited on needles in fall and hatch in spring.
LARVAE feed on needles in spring and summer.
PUPAE attach to needles in late summer.
ADULTS emerge, mate, lay eggs, and die in late summer or early fall.
CONTROL Environmentally acceptable chemicals have not been developed for control of this insect. Natural control (predators and parasites) is relied upon.

Figure 9.--Field display describing proposed pine butterfly field experiment.

Figure 10.--Office display describing proposed pine butterfly field experiment.

## RESULTS AND DISCUSSION

Aerial spray operations.--Egg hatch began as early as May 21. By early June virtually all eggs had hatched at the lower elevations and instar I larvae were actively feeding. The mexacarbate treatments 0.15 pound per acre and 0.30 pound per acre were applied on June 4 and 5, 1973, respectively.

*Bacillus thuringiensis* one-half pound per acre treatment was applied June 19 and the 1 pound per acre treatment was applied June 20. Larvae were predominately in instars II and III by this time, although some of the higher elevation test blocks still had a preponderance of instar I larvae.

Treatment was applied during the early morning hours, between 5 and 6:30 a.m., to obtain maximum advantage of cool and relatively calm atmospheric conditions associated with stable to neutral vertical temperature conditions predominating. Weather conditions were nearly optimum on each spray date; air currents ranged from a dead calm at onset of spraying to a maximum of 5 m.p.h. downslope winds toward the end of each day's spray period. On site meteorological monitoring permitted spray pilots to compensate for downslope breezes by offsetting accordingly. An average of 10 minutes active

spray time was required to treat each plot. The mexacarbate treatments were completed with one helicopter and the *Bacillus thuringiensis* was applied with two helicopters.

Population reduction.--Mean cluster prespray larval population densities in the mexacarbate blocks ranged from a moderate level of over one insect per linear inch of foliated branch (Smith Creek) to a low of 0.23 larva per linear inch of foliated branch (Canyon Creek) (Tables 1 and 2). Four-day postspray counts for both treatments showed a high population reduction with only two cluster plots in the 0.15 pound per acre treatment and three cluster plots in the 0.30 pound per acre treatment, falling below a corrected population reduction of 95 percent (Table 1). Mean reduction of larval densities averaged over 96 percent for both dosages with treatment difference so slight we concluded that there was no statistically significant difference between the 0.15 and 0.30 pound per acre treatment. Mortality attributed to natural factors in the untreated checks for the same 4-day period was 16.01 percent (0.8399 survival ratio) (Table 2).

Mean cluster prespray larval population density estimates for *Bacillus thuringiensis* treatment blocks were considerably lower than for the mexacarbate blocks, ranging from 0.07 to 0.30 larva per inch of foliated branch (Table 5). This is believed primarily due to sampling later in the larval feeding period (instar I vs. instars II and III) at which time a certain degree of mortality from natural causes had taken place. Individual cluster sample mortality estimates were erratic during three postspray sampling periods for the one-half pound per acre treatment, with the most erratic pattern occurring in areas of lightest prespray population density. This inconsistency may be partially explained by the lower than anticipated population densities in the treatment blocks which could not be measured with a sufficiently high level of confidence (Table 3) with the sampling system developed for this test. It is interesting to note that the one-half pound per acre replicate with the highest population density (Gash Creek) showed the most consistent pattern of population reduction over the three postspray sampling periods. Overall population reduction after 13 days for the one-half pound per acre treatment was 72.96 percent (Tables 4 and 5).

Data was somewhat more consistent for the 1 pound per acre treatment which averaged 92.16 percent after 12 days (Table 5), possibly due to higher prespray population levels coupled with a higher dosage rate. Survival ratios in the check blocks for the three postspray sampling periods were 0.9256, 0.7783, and 0.6519 for the 4-, 8-, and 12-day postspray samples respectively.

Deposit-mortality relationships.--The 80015 nozzle, pressure, and airspeed provided droplet spectra which averaged 277.90 microns VMD for the mexacarbate and 279.15 microns VMD for the *Bacillus thuringiensis* (Tables 6 and 7).

Table 1.--Individual cluster prespray and postspray pine butterfly population densities, survival ratios and mortality estimates, mexacarbate field experiment, Bitterroot National Forest, Montana, June 1973.

| Dosage | Replicate | Cluster | Prespray larval density[1/] | 4-day postspray density[1/] | Survival ratio | Corrected percent mortality[2/] |
|---|---|---|---|---|---|---|
| 0.15 lb/ acre | Mill Creek | 351-60 | 0.9600 ± .1390 | .1029 ± .0332 | .1072 | 87.24 |
| | | 361-70 | .9257 ± .1651 | .0092 ± .0092 | .0099 | 98.83 |
| | | 371-80 | .6655 ± .1190 | .1222 ± .0386 | .1836 | 78.15 |
| | | 381-90 | .9415 ± .1775 | .0227 ± .0113 | .0241 | 97.13 |
| | | 391-400 | 1.1083 ± .1916 | .0188 ± .0089 | .0170 | 97.78 |
| | Bear Creek | 901-10 | .0631 ± .0248 | 0 0 | 0 | 100.00 |
| | | 911-20 | .0192 ± .0089 | 0 0 | 0 | 100.00 |
| | | 921-30 | .8200 ± .2091 | .0007 ± .0007 | .0007 | 99.92 |
| | | 931-40 | .5177 ± .0854 | 0 0 | 0 | 100.00 |
| | | 941-50 | 0 0 | 0 0 | -- | -- |
| | Smith Creek | 301-10 | .5508 ± .1412 | 0 0 | 0 | 100.00 |
| | | 311-20 | 1.6639 ± .4349 | .0090 ± .0052 | .0054 | 99.36 |
| | | 321-30 | .9645 ± .2262 | .0140 ± .0085 | .0145 | 98.27 |
| | | 331-40 | .9948 ± .1316 | .0175 ± .0091 | .0176 | 97.90 |
| | | 341-50 | .9432 ± .2368 | 0 0 | 0 | 100.00 |
| 0.30 lb/ acre | Blodgett Cr. | 701-10 | .3602 ± .0837 | .0213 ± .0138 | .0591 | 92.97 |
| | | 711-20 | .8607 ± .2187 | 0 0 | 0 | 100.00 |
| | | 721-30 | .6515 ± .1582 | 0 0 | 0 | 100.00 |
| | | 731-40 | .4347 ± .1917 | 0 0 | 0 | 100.00 |
| | | 741-50 | .2733 ± .0618 | 0 0 | 0 | 100.00 |
| | Big Creek | 251-60 | 1.2014 ± .3045 | .0328 ± .0152 | .0273 | 96.75 |
| | | 261-70 | .5834 ± .1607 | .0537 ± .0192 | .0921 | 89.03 |
| | | 271-80 | 1.0698 ± .3178 | .0049 ± .0035 | .0046 | 99.45 |
| | | 281-90 | .2708 ± .0623 | 0 0 | 0 | 100.00 |
| | | 291-300 | .4053 ± .0971 | .0085 ± .0046 | .0297 | 97.03 |
| | Canyon Creek | 1-10 | .1216 ± .0327 | .0344 ± .0200 | .2828 | 66.63 |
| | | 11-20 | .3652 ± .0820 | 0 0 | 0 | 100.00 |
| | | 21-30 | .3407 ± .0781 | 0 0 | 0 | 100.00 |
| | | 31-40 | .1708 ± .0707 | .0322 ± .0226 | .0187 | 97.77 |
| | | 41-50 | .1485 ± .0495 | .0357 ± .0122 | .2404 | 71.38 |

1/ Larvae per linear inch of foliated branch.

2/ Corrected for natural mortality in check blocks. Survival ratio in check blocks was .8399.

Table 2.--Prespray and postspray pine butterfly larval population density and percent population reduction summary, mexacarbate field experiment, Bitterroot National Forest, Montana, June 1973

| Dosage | Replicate | Prespray density[1/] | 4-day postspray density | Survival ratio | Corrected percent control[2/] |
|---|---|---|---|---|---|
| 0.15 lb./acre | Mill Creek | 0.9189 | 0.0554 | 0.0603 | 92.82 |
| | Bear Creek | .2787 | .0001 | .0004 | 99.95 |
| | Smith Creek | 1.0256 | .0081 | .0079 | 99.06 |
| | Treatment mean | .7410 | .0213 | .0287 | 96.58 |
| 0.30 lb./acre | Blodgett Creek | .5149 | .0043 | .0084 | 99.08 |
| | Big Creek | .7049 | .0199 | .0282 | 96.64 |
| | Canyon Creek | .2317 | .0149 | .0643 | 92.35 |
| | Treatment mean | .4836 | .0131 | .0271 | 96.77 |

1/ Larvae per inch of foliated branch

2/ Corrected for natural mortality. Survival ratio in check blocks was 0.8399.

Little in the way of conclusions can be drawn at this time from deposit-mortality relationships for the mexacarbate data due to the consistently high population reductions achieved. Almost all of the individual cluster samples averaged in excess of 95 percent population reduction.

A more positive relationship between droplet density and percent mortality occurred in two of the one-half pound per acre Bt blocks. In each case, one of the five sample points received a low spray deposit. This was accompanied by a measured 0 or negative mortality after 12 days (Table 7). Relationship between droplet density and mortality closely followed the pattern described for mexacarbate for the remaining Bt blocks.

Foliage assessment.--Observations made during late July, at which time larval feeding commenced, indicated that very little noticeable defoliation had occurred in the Bitterroot Valley. This was due to a general decline of the infestation due to a complex of natural causes including poor egg viability, predation, and parasitism. Followup egg mass surveys conducted during September 1973 (Meyer and Ciesla 1973) indicated that a small subepidemic population persisted in the area of infestation, but little if any defoliation was anticipated in 1974. On-the-ground examination of treatment plots within surrounding areas indicated very little difference in intensities of feeding injury. New growth on trees which suffered moderate to heavy defoliation in 1972 masked the previous year's feeding, giving the entire area of infestation the appearance of having "greened up." Consequently, we felt that planned aerial photo mission of spray blocks and surrounding unsprayed stands would provide little if any data of value and was not carried out.

Table 3.--Individual cluster prespray and postspray pine butterfly larval population densities, *Bacillus thuringiensis* field experiment, Bitterroot National Forest, Montana, June 1973

| Dosage | Replicate | Cluster | Prespray larval density 1/ | Postspray larval density | | |
|---|---|---|---|---|---|---|
| | | | | 4-day | 8-day | 12-day |
| ½ lb/ acre | Gash Creek | 1301-10 | .1425 ± .0291* | .0272 ± .0093 | .0435 ± .0124 | .0133 ± .0042 |
| | | 1311-20 | .1928 ± .0322 | .0355 ± .0076 | .0473 ± .0121 | .0358 ± .0131 |
| | | 1321-30 | .2542 ± .0421 | .0463 ± .0018 | .0050 ± .0026 | .0188 ± .0096 |
| | | 1331-40 | .5224 ± .0614 | .0887 ± .0023 | .0873 ± .0201 | .0517 ± .0179 |
| | | 1341-50 | .3973 ± .0536 | .0318 ± .0066 | .0510 ± .0124 | .0636 ± .0987 |
| | E.Sweeney Creek | 1201-10 | .1222 ± .0463 | .0098 ± .0062 | .0522 ± .0128 | .0132 ± .0049 |
| | | 1211-20 | .0440 ± .0187 | .0053 ± .0033 | .0185 ± .0722 | .0590 ± .0171 |
| | | 1221-30 | .4042 ± .1030 | .0353 ± .0149 | .0642 ± .0224 | .0647 ± .0175 |
| | | 1231-40 | .0702 ± .0243 | .0147 ± .0077 | .0349 ± .0147 | .0173 ± .0123 |
| | | 1241-50 | .1137 ± .0483 | .0023 ± .0023 | .0138 ± .0076 | .0023 ± .0023 |
| | W.Sweeney Creek | 1001-10 | .0758 ± .0207 | .0222 ± .0078 | .0139 ± .0047 | .0162 ± .0044 |
| | | 1011-20 | .1385 ± .0399 | .0227 ± .0069 | .0291 ± .0075 | .0417 ± .0087 |
| | | 1021-30 | .0413 ± .0156 | .0200 ± .0077 | .0059 ± .0040 | .0503 ± .0148 |
| | | 1031-40 | .0663 ± .0218 | .0148 ± .0081 | 0 0 | .0092 ± .0038 |
| | | 1041-50 | .0481 ± .0205 | .0368 ± .0238 | .0127 ± .0075 | .0062 ± .0043 |
| 1 lb/ acre | S. Bear Creek | 1501-10 | .2603 ± .0424 | .0107 ± .0076 | .0065 ± .0029 | 0 0 |
| | | 1511-20 | .3163 ± .0525 | .0243 ± .0066 | .0022 ± .0022 | 0 0 |
| | | 1521-30 | .1663 ± .0279 | .0363 ± .0149 | .0382 ± .0105 | .0034 ± .0025 |
| | | 1531-40 | .1242 ± .0214 | .0111 ± .0046 | 0 0 | .0092 ± .0066 |
| | | 1541-50 | .1736 ± .0247 | .0386 ± .0087 | .0463 ± .0188 | .0198 ± .0080 |
| | Blodgett Cr. (S.) | 801-10 | .2905 ± .0513 | .0969 ± .0283 | .0322 ± .0114 | .0550 ± .0140 |
| | | 811-20 | .2727 ± .0479 | .0313 ± .0141 | .0089 ± .0044 | .0160 ± .0085 |
| | | 821-30 | .1866 ± .0495 | .0528 ± .0305 | .0097 ± .0049 | .0163 ± .0065 |
| | | 831-40 | .2843 ± .0527 | .0152 ± .0070 | . 0 0 | 0 0 |
| | | 841-50 | .2725 ± .0625 | .0525 ± .0209 | .0217 ± .0217 | .0042 ± .0042 |
| | Sawdust Creek | 501-10 | .2930 ± .0769 | .0951 ± .0227 | .0312 ± .0126 | .0462 ± .0159 |
| | | 511-20 | .1957 ± .0365 | .0235 ± .0097 | .0092 ± .0048 | .0086 ± .0036 |
| | | 521-30 | .0693 ± .0199 | .0306 ± .0146 | .0065 ± .0044 | .0042 ± .0026 |
| | | 531-40 | .2308 ± .0419 | .0583 ± .0179 | .0207 ± .0083 | .0128 ± .0083 |
| | | 541-50 | .2882 ± .0505 | .0763 ± .0259 | .0232 ± .0104 | .0088 ± .0034 |

1/ Larvae per linear inch of foliated branch.

* ± 1 S.E.

Table 4.--Individual cluster survival ratios and mortality estimates, *Bacillus thuringiensis* field experiment, Bitterroot National Forest, Montana, June 1973.

| Dosage | Replicate | Cluster | Survival ratio | | | Corrected percent mortality[1/] | | |
|---|---|---|---|---|---|---|---|---|
| | | | 4-day | 8-day | 12-day | 4-day | 8-day | 12-day |
| ½ lb/ acre | Gash Creek | 1301-10 | .1909 | .3053 | .0933 | 79.38 | 60.77 | 85.69 |
| | | 1311-20 | .1841 | .2453 | .1857 | 80.11 | 68.48 | 71.51 |
| | | 1321-30 | .1821 | .0197 | .0740 | 80.33 | 97.47 | 88.65 |
| | | 1331-40 | .1698 | .1671 | .0990 | 81.66 | 78.54 | 84.81 |
| | | 1341-50 | .0803 | .1284 | .1603 | 91.32 | 83.51 | 75.41 |
| | E. Sweeney Creek | 1201-10 | .0802 | .4272 | .1080 | 91.34 | 44.85 | 83.43 |
| | | 1211-20 | .1205 | .4205 | 1.3409 | 86.98 | 45.97 | 0 |
| | | 1221-30 | .0873 | .1588 | .1601 | 90.57 | 79.60 | 75.44 |
| | | 1231-40 | .2097 | .4979 | .2468 | 77.34 | 36.03 | 62.14 |
| | | 1241-50 | .0202 | .1214 | .0202 | 97.82 | 84.40 | 96.90 |
| | W. Sweeney Creek | 1001-10 | .2929 | .1834 | .2137 | 68.36 | 76.44 | 67.22 |
| | | 1011-20 | .1639 | .2108 | .3010 | 82.29 | 72.92 | 53.83 |
| | | 1021-30 | .4843 | .1429 | 1.2179 | 47.68 | 81.64 | 86.82 |
| | | 1031-40 | .2232 | 0 | .1388 | 75.89 | 100.00 | 78.91 |
| | | 1041-50 | .7651 | .2640 | .1289 | 17.34 | 66.08 | 80.23 |
| 1 lb/ acre | S. Bear Creek | 1501-10 | .0411 | .0250 | 0 | 95.56 | 96.79 | 100.00 |
| | | 1511-20 | .0768 | .0070 | 0 | 91.70 | 99.10 | 100.00 |
| | | 1521-30 | .2183 | .2297 | .0204 | 76.42 | 70.49 | 96.87 |
| | | 1531-40 | .0894 | 0 | .0741 | 90.34 | 100.00 | 88.63 |
| | | 1541-50 | .2229 | .2667 | .1141 | 75.92 | 65.73 | 82.50 |
| | Blodgett Cr. (S.) | 801-10 | .3336 | .1108 | .1893 | 63.96 | 85.76 | 70.96 |
| | | 811-20 | .1148 | .0326 | .0587 | 87.60 | 95.81 | 91.00 |
| | | 821-30 | .2833 | .0520 | .0520 | 69.39 | 93.32 | 92.02 |
| | | 831-40 | .0535 | 0 | 0 | 94.22 | 100.00 | 100.00 |
| | | 841-50 | .1927 | .0081 | .0081 | 79.18 | 98.96 | 98.76 |
| | Sawdust Creek | 501-10 | .3246 | .1065 | .1577 | 64.93 | 86.32 | 75.81 |
| | | 511-20 | .1201 | .0470 | .0470 | 87.02 | 93.96 | 92.79 |
| | | 521-30 | .4430 | .0938 | .0606 | 52.04 | 87.95 | 90.70 |
| | | 531-40 | .2526 | .0897 | .0555 | 72.71 | 88.47 | 91.49 |
| | | 541-50 | .2647 | .0805 | .0305 | 73.20 | 89.66 | 95.32 |

1/ Corrected for natural mortality in check blocks. Survival ratios in check blocks were .9256, .7783, and .6519 for 4-, 8-, and 12-day postspray samples, respectively.

Table 5.--Prespray and postspray pine butterfly larval population densities and percent population reduction summary, *Bacillus thuringiensis* field experiment, Bitterroot National Forest, Montana, June 1973.

| Dosage | Replicate | Percent reduction[1/] | | | | |
|---|---|---|---|---|---|---|
| | | Prespray density[2/] | 4-day postspray density | 8-day postspray density | 12-day postspray density | 12-day postspray population density[2/] |
| ½ lb B.t./acre | Gash Creek | 0.3019 | 82.56 | 77.83 | 81.33 | 0.0367 |
| | E. Sweeney | .1505 | 88.81 | 58.22 | 67.69 | .0317 |
| | W. Sweeney | .0742 | 58.31 | 79.42 | 38.63 | .0247 |
| | Treatment mean | .1758 | 83.04 | 77.27 | 72.96 | .0310 |
| 1 lb B.t./acre | S. Bear | .2091 | 85.99 | 80.52 | 93.60 | .0065 |
| | Blodgett | .2613 | 78.77 | 94.77 | 93.66 | .0183 |
| | Sawdust | .2154 | 78.87 | 89.27 | 89.23 | .0162 |
| | Treatment mean | .2288 | 79.36 | 91.12 | 92.16 | .0137 |

1/ Corrected for natural mortality in check blocks. Survival ratios in check blocks were: 0.9256 (4-day)
.7783 (8-day)
.6519 (12-day)

2/ Number of larvae per inch of foliated branch.

Table 6.--Deposit-mortality summary, mexacarbate field experiment, Bitterroot National Forest, June 1973

| Dosage | Replicate | Tree cluster | Droplet density $mg/m^2$ (x) | Corrected percent mortality (y) | Volume median diameter (VMD) |
|---|---|---|---|---|---|
| 0.15 lb./acre | Mill Cr. | 351-60 | 160 | 87.24 | 321 |
| | | 361-70 | 276 | 98.83 | 316 |
| | | 371-80 | 111 | 78.15 | 305 |
| | | 381-90 | 129 | 97.13 | 260 |
| | | 391-400 | 103 | 97.78 | 266 |
| | | Overall | 157 | | 299 |
| | Bear Cr. | 901-10 | 314 | 100.00 | 269 |
| | | 911-20 | 300 | 100.00 | 282 |
| | | 921-30 | 518 | 99.92 | 346 |
| | | 931-40 | 159 | 100.00 | 254 |
| | | 941-50 | 257 | 100.00 | 288 |
| | | Overall | 310 | | 297 |
| | Smith Cr. | 301-10 | 188 | 100.00 | 237 |
| | | 311-20 | 118 | 99.36 | 226 |
| | | 321-30 | 144 | 98.27 | 237 |
| | | 331-40 | 141 | 97.90 | 243 |
| | | 341-50 | 336 | 100.00 | 276 |
| | | Overall | 186 | | 250 |
| 0.30 lb./acre | Blodgett Creek | 701-10 | 108 | 92.97 | 257 |
| | | 711-20 | 263 | 100.00 | 287 |
| | | 721-30 | 320 | 100.00 | 293 |
| | | 731-40 | 199 | 100.00 | 319 |
| | | 741-50 | 244 | 100.00 | 289 |
| | | Overall | 226 | | 292 |
| | Big Creek | 251-60 | 128 | 96.75 | 257 |
| | | 261-70 | 106 | 89.03 | 259 |
| | | 271-80 | 226 | 99.45 | 252 |
| | | 281-90 | 242 | 100.00 | 256 |
| | | 291-300 | 133 | 97.03 | 233 |
| | | Overall | 167 | | 251 |
| | Canyon Creek | 1-10 | 353 | 66.63 | 363 |
| | | 11-20 | 339 | 100.00 | 340 |
| | | 21-30 | 289 | 100.00 | 314 |
| | | 31-40 | 157 | 97.77 | 251 |
| | | 41-50 | 97 | 71.38 | 241 |
| | | Overall | 248 | | 317 |

Table 7.--Deposit-mortality summary, *Bacillus thuringiensis* field experiment, Bitterroot National Forest, Montana, June 1973

| Dosage | Replicate | Tree cluster | Droplet density $mg/m^2$ (x) | Corrected percent mortality (y) | Volume median diameter (VMD) |
|---|---|---|---|---|---|
| 1/2 lb./acre | Gash Creek | 1301-10 | 147 | 85.69 | 284 |
| | | 1311-20 | 177 | 71.51 | 318 |
| | | 1321-30 | 287 | 88.65 | 277 |
| | | 1331-40 | 372 | 84.81 | 324 |
| | | 1341-50 | 132 | 75.41 | 324 |
| | | Overall | 222 | | 306 |
| | E. Sweeney Creek | 1201-10 | 264 | 83.43 | 283 |
| | | 1211-20 | 101 | 0 | 274 |
| | | 1221-30 | 177 | 75.44 | 265 |
| | | 1231-40 | 123 | 62.14 | 308 |
| | | 1241-50 | 391 | 96.90 | 298 |
| | | Overall | 212 | | 288 |
| | W. Sweeney Creek | 1001-10 | 198 | 67.22 | 291 |
| | | 1011-20 | 120 | 53.83 | 285 |
| | | 1021-30 | 76 | 0 | 330 |
| | | 1031-40 | 264 | 78.71 | 206 |
| | | 1041-50 | 358 | 80.23 | 307 |
| | | Overall | 204 | | 304 |
| 1 lb./acre | S. Bear Creek | 1501-10 | 206 | 100.00 | 266 |
| | | 1511-20 | 362 | 100.00 | 280 |
| | | 1521-30 | 208 | 96.87 | 314 |
| | | 1531-40 | 214 | 88.63 | 259 |
| | | 1541-50 | 79 | 82.50 | 271 |
| | | Overall | 213 | | 276 |
| | Blodgett Creek | 801-10 | 49 | 70.96 | 275 |
| | | 811-20 | 54 | 91.00 | 265 |
| | | 821-30 | 75 | 92.02 | 287 |
| | | 831-40 | 154 | 100.00 | 254 |
| | | 841-50 | 120 | 98.76 | 264 |
| | | Overall | 90 | | 265 |
| | Sawdust Cr. | 501-10 | 52 | 75.81 | 273 |
| | | 511-20 | 116 | 92.79 | 262 |
| | | 521-30 | 36 | 90.70 | 245 |
| | | 531-40 | 40 | 91.49 | 231 |
| | | 541-50 | 72 | 95.32 | 254 |
| | | Overall | 64 | | 256 |

Effects on nontarget insects.--Drop cloths were examined 4 hours after spraying. Even though rocks were placed in the cloths, strong, gusty winds inverted the cloths in the 0.30 pound Zectran treatment and all but one cloth in the Bear Creek 0.15 pound Zectran plot, causing the contents to be lost. It is also possible that some of the insects in the remaining cloths were lost. Dipterans and hymenopterans were the most common nontarget insects found in the cloths. Some coleopterans and hemipterans were also found. In addition to insects, a number of spiders were apparently killed by the mexacarbate treatment (Table 8). Insects were identified, where possible, to the family level by an entomologist.

## CONCLUSIONS

Zectran FS-15 applied at the rate of 0.15 pound per acre and a 1.0 pound per acre dosage of Dipel are recommended for pilot testing.

This test was conducted under near optimum conditions. There were no difficulties with the equipment and meteorological conditions were ideal. Intensive coordination (briefing, site surveys, and critiques) among all project personnel was conducted throughout this project. These factors undoubtedly contributed significantly to the project success.

Pine butterfly population levels were significantly lower in 1973 than in 1972. By September of 1973 the population had declined due to natural factors to near endemic levels. Whether or not this condition influenced test results is unknown. However, populations in the check blocks remained quite constant. The survival ratio after treatment for the 4-day postspray sample was 84 percent in the Zectran check plots and 65 percent for the 12-day postspray sample in the Dipel check plots. This supports crediting the changes in population levels during the test period to the treatment rather than natural causes.

Table 8.--Summary of drop cloth collections, mexacarbate field experiment, Bitterroot National Forest, Montana, June 1973.

| Replicate | Tree No. | Total non-target arthropods | Diptera (Family) | Hymenoptera (Family) | Coleoptera (Family) | Hemiptera (Family) | Arachnida |
|---|---|---|---|---|---|---|---|
| Smith Creek | 302 | 3 | 1 Sarcophagidae | 1 Formicidae | 1 Buprestidae | | |
| | 312 | 5 | 2 Sarcophagidae<br>2 Chironomidae | 1 Ichneumonidae | | | |
| | 322 | 7 | 2 Chironomidae<br>1 Cecidomyiidae<br>1 Sarcophagidae<br>1 Simulidae | 1 Braconidae<br>1 Unidentified | | | |
| | 340 | 6 | 4 Chironomidae<br>1 Unidentified | | | | 1 |
| | 348 | 18 | 3 Chironomidae<br>3 Empididae<br>1 Sarcophagidae<br>1 Anthomyiidae<br>2 Unidentified | | | 4 Unidentified nymphs | |
| Mill Creek | 383 | 15 | 3 Empididae<br>3 Chironomidae<br>2 Sarcophagidae | 4 Ichneumonidae | 1 Elateridae | | 2 |
| | 380 | 3 | | 1 Ichneumonidae | | | 2 |
| | 398 | 16 | 6 Chironomidae<br>1 Sarcophagidae<br>1 Trypetidae<br>1 Anthomyiidae<br>1 Unidentified | 3 Ichneumonidae<br>1 Chrysididae | | 1 Pentatomidae | 1 |
| | 366 | 7 | 2 Chironomidae | 2 Ichneumonidae<br>1 Chalcidae | 1 Curculionidae | | 1 |
| | 352 | 5 | | 2 Ichneumonidae<br>1 Formicidae<br>1 Unidentified | 1 Buprestidae | | |
| Bear Creek | 909 | 19 | 1 Sarcophagidae | 15 Formicidae<br>1 Ichnoeumonidae | | 1 Unidentified | 1 |

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